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Heterogeneous network traffic possesses diverse statistical properties which include complex temporal correlation and non-Gaussian distributions. A challenge to modeling heterogeneous traffic is to develop a traffic model which can accurately characterize these statistical properties, which is computationally efficient, and which is feasible for analysis. This work develops wavelet traffic models for tackling these issues. In specific, we model the wavelet coefficients rather than the original traffic. Our approach is motivated by a discovery that although heterogeneous network traffic has the complicated short- and long-range temporal dependence, the corresponding wavelet coefficients are all "short-range" dependent. Therefore, a simple wavelet model may be able to accurately characterize complex network traffic. We first investigate what short-range dependence is important among wavelet coefficients. We then develop the simplest wavelet model, i.e., the independent wavelet model for Gaussian traffic. We define and evaluate the (average) autocorrelation function and the buffer loss probability of the independent wavelet model for Fractional Gaussian Noise (FGN) traffic. This assesses the performance of the independent wavelet model, and the use of which for analysis. We also develop (low-order) Markov wavelet models to capture additional dependence among wavelet coefficients. We show that an independent wavelet model is sufficiently accurate, and a Markov wavelet model only improves the performance marginally. We further extend the wavelet models to non-Gaussian traffic through developing a novel time-scale shaping algorithm. The algorithm is tested using real network traffic and shown to outperform FARIMA in both efficiency and accuracy. Specifically, the wavelet models are parsimonious, and have the computation complexity O (N) in developing a model from a training sequence of length N, and O(M) in generating a synthetic traffic trace of length M.

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h c gc cf

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1. Document ID: US 20020143929 A1

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L21: Entry 1 of 1

File: PGPB

Oct 3, 2002

PGPUB-DOCUMENT-NUMBER: 20020143929

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020143929 A1

TITLE: Method and system for collection and storage of traffic data from

<u>heterogeneous network</u> elements in a computer <u>network</u>

PUBLICATION-DATE: October 3, 2002

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47

Maltz, David A. Los Altos CA US Broch, Joshua G. Cupertino CA US

Dunn, P. Bradley Palo Alto CA US

US-CL-CURRENT: 709/224; 709/226

Title   Citation   Front   Review   Classification   Date   Reference   Sequences   Attachm	nents Claims 1999
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Term	Documents
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NETWORKABILITY	23
NETWORKABLE	327
NETWORKAC	1
NETWORKACCESS	5
NETWORKACCESSIBLE	2
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# 1. Document ID: US 20040117476 A1

Using default format because multiple data bases are involved.

L22: Entry 1 of 3

File: PGPB

Jun 17, 2004

PGPUB-DOCUMENT-NUMBER: 20040117476

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20040117476 A1

TITLE: Method and system for performing load balancing across control planes in a

data center

PUBLICATION-DATE: June 17, 2004

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47 Steele, Doug Fort Collins CO US Hogan, Katherine Fort Collins CO US Schloss, Rheid Fort Collins US · CO

US-CL-CURRENT: 709/224; 709/225

Full Title Citation Front Rev	iem Classification Date Referen	e Sequences Attachments	Claims KWWC Draw. Dr
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2. Document ID: US 20020019869 A1

L22: Entry 2 of 3

File: PGPB

Feb 14, 2002

PGPUB-DOCUMENT-NUMBER: 20020019869

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020019869 A1

TITLE: System and method for modeling and provisioning information system capacity

PUBLICATION-DATE: February 14, 2002

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47 Goldszmidt, Moises Moss Beach CA US Sabata, Bikash Menlo Park CA US Palma, Derek Union City CA US Raha, Amitava San Jose CA US

h e b b g e e e f b e

US-CL-CURRENT: 709/224; 709/227

Full Title Citation Front Review Classification Date Reference Sequences Attachments Claims KMC Draw De

3. Document ID: US 5761502 A

L22: Entry 3 of 3

File: USPT

Jun 2, 1998

US-PAT-NO: 5761502

DOCUMENT-IDENTIFIER: US 5761502 A

TITLE: System and method for managing a telecommunications network by associating

and correlating network events

DATE-ISSUED: June 2, 1998

INVENTOR-INFORMATION:

NAME CITY STATE ZIP CODE COUNTRY

Jacobs; Andrew Robin Colorado Springs CO

Full Title Citation Front Review Classification Date Reference

US-CL-CURRENT: 707/103R; 379/221.09, 379/221.15, 379/279, 707/10, 709/242, 714/26

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NETWORKA	42
NETWORKABILITY	23
NETWORKABLE	327
NETWORKAC	1
NETWORKACCESS	5
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**Search Results** - Record(s) 1 through 4 of 4 returned.

1. Document ID: US 6687750 B1

Using default format because multiple data bases are involved.

L38: Entry 1 of 4

File: USPT

Feb 3, 2004

US-PAT-NO: 6687750

DOCUMENT-IDENTIFIER: US 6687750 B1

TITLE: Network traffic visualization

DATE-ISSUED: February 3, 2004

INVENTOR-INFORMATION:

NAME

CITY

STATE

ZIP CODE

COUNTRY

Messinger; Fred

Groton

MA

Swallow; George

Concord

MA

US-CL-CURRENT: <u>709/224</u>; <u>703/6</u>, <u>709/202</u>, <u>709/217</u>, <u>709/223</u>, <u>709/229</u>, <u>713/201</u>, <u>714/47</u>

2. Document ID: US 6223188 B1

L38: Entry 2 of 4

File: USPT

Apr 24, 2001

US-PAT-NO: 6223188

DOCUMENT-IDENTIFIER: US 6223188 B1

TITLE: Presentation of link information as an aid to hypermedia navigation

DATE-ISSUED: April 24, 2001

INVENTOR-INFORMATION:

NAME

CITY

STATE

ZIP CODE

COUNTRY

Albers; Michael C.

San Francisco

CA

Bergman; Eric D.

Palo Alto

CA

US-CL-CURRENT: <u>715/501.1</u>

Full Title Citation Front Review Classification Date Reference

h eb bgeeef e ef be

3. Document ID: US 5706436 A

L38: Entry 3 of 4

File: USPT

Jan 6, 1998

US-PAT-NO: 5706436

DOCUMENT-IDENTIFIER: US 5706436 A

\*\* See image for Certificate of Correction \*\*

TITLE: Apparatus and method for evaluation network traffic performance

DATE-ISSUED: January 6, 1998

INVENTOR-INFORMATION:

NAME

CITY

STATE

ZIP CODE

COUNTRY

Lewis; Lundy

Mason

NH

Datta; Utpal

Bedford

NH

US-CL-CURRENT: <u>709/235</u>; <u>703/21</u>, <u>709/224</u>

Full	Title	Citation	Front	Review	Classification	Date	Reference	Claims	KARC	Draw De
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4. Document ID: US 5640504 A

L38: Entry 4 of 4

File: USPT

Jun 17, 1997

US-PAT-NO: 5640504

DOCUMENT-IDENTIFIER: US 5640504 A

TITLE: Distributed computing network

DATE-ISSUED: June 17, 1997

INVENTOR-INFORMATION:

NAME

CITY

STATE ZIP CODE

COUNTRY

Johnson, Jr.; Harold E.

Newtown

PA

US-CL-CURRENT: 714/4; 713/2

Full	Title Citation Front Review Classification Date Reference		MC Draws De
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1. Document ID: US 20040172466 A1

Using default format because multiple data bases are involved.

L3: Entry 1 of 8

File: PGPB

Sep 2, 2004

Nov 28, 2002

PGPUB-DOCUMENT-NUMBER: 20040172466

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20040172466 A1

TITLE: Method and apparatus for monitoring a network

PUBLICATION-DATE: September 2, 2004

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47

Douglas, Christopher Paul Loveland CO US
Dorland, Chia-Chu Fort Collins CO US

US-CL-CURRENT: 709/224; 345/736

Full Title	Citation Fron	t Review			Sequences	Attachments	Claims	KAMC	Draws De
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File: PGPB

2. Document ID: US 20020177907 A1

PGPUB-DOCUMENT-NUMBER: 20020177907

PGPUB-FILING-TYPE: new

L3: Entry 2 of 8

DOCUMENT-IDENTIFIER: US 20020177907 A1

TITLE: Method and apparatus for replaying and visualizing post-performance metrics

for a complex heterogeneous data space

PUBLICATION-DATE: November 28, 2002

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47

Hand, Leonard S. Trophy Club TX US Washburn, Jeffery R. Roanoke TX US

US-CL-CURRENT: 700/1

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Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KMC | Draw De

3. Document ID: US 20020175956 A1

L3: Entry 3 of 8

File: PGPB

Nov 28, 2002

PGPUB-DOCUMENT-NUMBER: 20020175956

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020175956 A1

TITLE: Method and apparatus for efficiently exposing nodes of a display map while

monitoring metrics in a complex heterogeneous system

PUBLICATION-DATE: November 28, 2002

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47

Hand, Leonard S. Trophy Club TX US Washburn, Jeffery R. Roanoke TX US

US-CL-CURRENT: 345/853

Full Title Citation Front Review Classification Date Reference Sequences Attachments Claims 1000C Draw De

4. Document ID: US 20020175941 A1

L3: Entry 4 of 8 File: PGPB Nov 28, 2002

PGPUB-DOCUMENT-NUMBER: 20020175941

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020175941 A1

TITLE: Method and apparatus for visualizing metrics in a data space

PUBLICATION-DATE: November 28, 2002

INVENTOR-INFORMATION:

NAME CITY STATE COUNTRY RULE-47

Hand, Leonard S. Ft. Worth TX US Washburn, Jeffery R. Roanoke TX US

US-CL-CURRENT: 345/764

Full Title Citation Front Review Classification Date Reference Sequences Attachments Claims KMC Draw Do

5. Document ID: US 20020175934 A1

L3: Entry 5 of 8 File: PGPB Nov 28, 2002

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PGPUB-DOCUMENT-NUMBER: 20020175934

PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020175934 A1

TITLE: Method and apparatus for efficiently and dynamically updating monitored

metrics in a heterogeneous system

PUBLICATION-DATE: November 28, 2002

INVENTOR-INFORMATION:

NAME CITY COUNTRY STATE RULE-47

Hand, Leonard S. Trophy Club US TX Washburn, Jeffery R. Roanoke ΤX US

US-CL-CURRENT: <u>345/734</u>

Full Title Citation Front	Review Classification D	Date Reference	Sequences Attachmenta Claim	s KMIC Draw De

6. Document ID: US 20020175941 A1

L3: Entry 6 of 8 File: DWPI Nov 28, 2002

DERWENT-ACC-NO: 2003-265990

DERWENT-WEEK: 200326

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TITLE: Metrics monitoring and visualization method in dynamic data space, involves using graphical user interface that changes in order to reflect changes that occur

in selection of metrics

INVENTOR: HAND, L S; WASHBURN, J R

PRIORITY-DATA: 2001US-0865368 (May 25, 2001)

PATENT-FAMILY:

PUB-NO PUB-DATE LANGUAGE PAGES MAIN-IPC

US 20020175941 A1 November 28, 2002 012 G09G005/00

INT-CL (IPC):  $\underline{G09} \ \underline{G} \ \underline{5}/\underline{00}$ 

#### Full Title Citation Front Review Classification Date Reference Claims KWC Draw De

# 7. Document ID: US 20020175956 A1

L3: Entry 7 of 8 File: DWPI

Nov 28, 2002

DERWENT-ACC-NO: 2003-255365

DERWENT-WEEK: 200325

COPYRIGHT 2004 DERWENT INFORMATION LTD

TITLE: Node exposing method for monitoring components of dynamic heterogeneous system, involves updating display of node such that updated display reflects updated value of component

h e b b g ee e f ef е

INVENTOR: HAND, L S; WASHBURN, J R

PRIORITY-DATA: 2001US-0865394 (May 25, 2001)

PATENT-FAMILY:

PUB-NO PUB-DATE LANGUAGE PAGES MAIN-IPC

<u>US 20020175956 A1</u> November 28, 2002 012 G06F003/00

INT-CL (IPC):  $\underline{606} + \underline{3}/\underline{00}$ ;  $\underline{606} + \underline{13}/\underline{00}$ 

Full Title	Citation	Front R	eview Cla	ssification	Date	Reference		Claims	1000C	Drawa De
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# 8. Document ID: US 20020175934 A1

L3: Entry 8 of 8 File: DWPI Nov 28, 2002

DERWENT-ACC-NO: 2003-255363

DERWENT-WEEK: 200325

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TITLE: Dynamic network node metrics reporting method for complex <a href="heterogeneous system">heterogeneous system</a>, involves repeating probing of content delivery component for reporting

determine metric values to recipient graphical display interface

INVENTOR: HAND, L S; WASHBURN, J R

PRIORITY-DATA: 2001US-0865369 (May 25, 2001)

PATENT-FAMILY:

PUB-NO PUB-DATE LANGUAGE PAGES MAIN-IPC

<u>US 20020175934 A1</u> November 28, 2002 014 G06F013/00

INT-CL (IPC):  $\underline{G06} + \underline{13/00}$ 

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# **Search Results** - Record(s) 1 through 4 of 4 returned.

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Using default format because multiple data bases are involved.

L23: Entry 1 of 4

File: USPT

Oct 2, 2001

US-PAT-NO: 6298385

DOCUMENT-IDENTIFIER: US 6298385 B1

TITLE: Method and apparatus for optimizing playback of media files over a data

network

DATE-ISSUED: October 2, 2001

INVENTOR-INFORMATION:

NAME CITY STATE ZIP CODE COUNTRY

Sparks; Randall B. Lafayette CO
Turner; C. Reid Boulder CO
Weich; Craig I. Boulder CO
Lund; Arnold M. Louisville CO

US-CL-CURRENT: 709/233

t Review Classification Date Reference	Claims KWAC Draw.	
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2. Document ID: DE 10140161 A1

L23: Entry 2 of 4

File: EPAB Mar 20, 2003

PUB-NO: DE010140161A1

DOCUMENT-IDENTIFIER: DE 10140161 A1

TITLE: Method for controlling access of a multimedia client to a server providing multimedia data, whereby all the data is transferred to the client before playback

begins, thus ensuring optimum playback independent of network bandwidth

PUBN-DATE: March 20, 2003

INT-CL (IPC):  $\underline{G06} + \underline{3}/\underline{14}$ ;  $\underline{G06} + \underline{13}/\underline{00}$ 

Claims 10000	
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3. Document ID: US 6792468 B1

L23: Entry 3 of 4

File: DWPI

Sep 14, 2004

Mar 20, 2003

DERWENT-ACC-NO: 2004-666270

DERWENT-WEEK: 200465

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TITLE: Recorded media data playback method in data network, involves transmitting

requests obtained by conversion of <u>playback</u> control signal, to server by transmitting one request per unit time, to store respective frames in server

INVENTOR: BEALL, J E; BLOCH, E D; DURAND, G A; HILL, R

PRIORITY-DATA: 1999US-0441722 (November 16, 1999), 1996US-0733478 (October 18,

1996)

PATENT-FAMILY:

PUB-NO PUB-DATE LANGUAGE PAGES MAIN-IPC
US 6792468 B1 September 14, 2004 014 G06F015/16

INT-CL (IPC):  $\underline{G06} + \underline{15/16}$ 

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		4.	Document ID:	DE 10140161 A1							•	•

File: DWPI

DERWENT-ACC-NO: 2003-373224

DERWENT-WEEK: 200336

L23: Entry 4 of 4

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TITLE: Method for controlling access of a multimedia client to a server providing multimedia data, whereby all the data is transferred to the client before playback begins, thus ensuring optimum playback independent of network bandwidth

PRIORITY-DATA: 2001DE-1040161 (August 22, 2001)

PATENT-FAMILY:

PUB-NO PUB-DATE LANGUAGE PAGES MAIN-IPC
DE 10140161 A1 March 20, 2003 008 G06F003/14

INT-CL (IPC):  $\underline{G06} \ \underline{F} \ 3/14$ ;  $\underline{G06} \ \underline{F} \ 13/00$ 

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DYNAMICS	61823	

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